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WELDING STUDY ON TITANIUM ALLOYS

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APPLIED MANUFACTURING RESEARCH
AND PROCESS DEVELOPMENT
DEPARTMENT 290

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WELDING STUDY
ON TITANIUM ALLOYS

AMR PROJECT REPORT

GENERAL DYNAMICS
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ABSTRACT

Start
[This study demonstrates the value of ultrasonic treatment for one material that undergoes metallurgical decay when subjected to conventional or sophisticated welding practices.] Since the action of the ultrasonic treatment is purely mechanical, it follows that such difficult materials as molybdenum, columbium, tungsten or others should respond in similar fashion. Russian literature published in 1957 and work of a similar nature undertaken by U.S. investigators during 1958, dealing with this subject (see References page 6), are discussed.

[The segment of this study dealing with ultrasonics, confirms the more extensive work conducted in Russia. Metallurgical assurance that disastrous grain coarsening during welding can be averted through the use of ultrasonic vibrations] is certain to broaden the application of these materials for critical aerodynamic requirements.

[It is concluded that the introduction of ultrasonic vibrations in the GTA weld puddle effects considerable change in the microstructure of a titanium-6 aluminum-4 vanadium alloy, when compared to samples not exposed to this treatment. Bend test values confirm the beneficial behavior resulting therefrom. In contrast, cryogenic treatment of the welding gas or the use of extreme purity welding gas, did not produce any detectable metallurgical changes in the weld behavior of this alloy.]

Tabulated data resulting from samples welded with high purity welding gas, refrigerated welding gas and ultrasonic treatment are compared in this report.

Report No. AN62AMR6026, Welding Study of Titanium Alloys. Copies of this report are obtainable from Technical Services Department 290-3, Ext. 3791.

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Preparation of metallographic specimens

TITLE

WELDING STUDY ON TITANIUM ALLOYS

OBJECTIVE

To determine singular effect of extreme purity welding gases, ultrasonic vibrations, and cryogenic welding gas temperatures on the weld quality of a titanium alloy.

INTRODUCTION

The degrading effect of impurities on the weld properties of titanium alloys, particularly engineering ductility, is fully recognized. Similarly, the strong adverse display of low structural toughness attributable to a coarse grain metallographic pattern has become manifest.

Current welding practices provide for effective protection against atmospheric contamination by utilizing inert gas shielding devices. Any planned metallurgical improvement directly related to a reduction or elimination of extraneous impurities would therefore be identified with the quality of the welding gases.

Present fusion welding practices produce exaggerated grain growth with subsequent decay in critical engineering properties and no effective operational measures for resolving the problem have been forthcoming. Experimental studies, undertaken principally by Russian investigators, have demonstrated that desirable microscopic changes in fusion welds could be effected through the use of ultrasonic vibrations. Such vibrations, made to occur during weld solidification, serve to promote the formation of a small grain, uniform microstructure. Resulting mechanical property data supports the discipline imposed by grain size control and affirms such well known effect on the more common structural alloys.

One metallurgical benefit derived from the use of refrigerated welding gas for joining certain titanium alloys has been demonstrated by other aircraft companies. Such a measure has been devised to suppress the occurrence of a brittle microconstituent. Lack of knowledge surrounding the use of a refrigerated welding media for other latent metallurgical benefits provided a basis for this segment of our study.

CONCLUSIONS

- (a) The use of extreme purity welding gas does not reflect any significant improvement in the weld ductility of a titanium-6 aluminum-4 vanadium alloy, when compared to samples joined with regularly supplied welding gas.
- (b) The introduction of ultrasonic vibrations in the weld puddle effects considerable change in the microstructure of a titanium-6 aluminum-4 vanadium alloy, when compared to samples that have not been exposed to this treatment. Bend test values serve to confirm the beneficial behavior resulting therefrom. Samples welded without ultrasonic attachment are shown in Fig. 1, (A) and (B), 50X, Krolls Reagent.

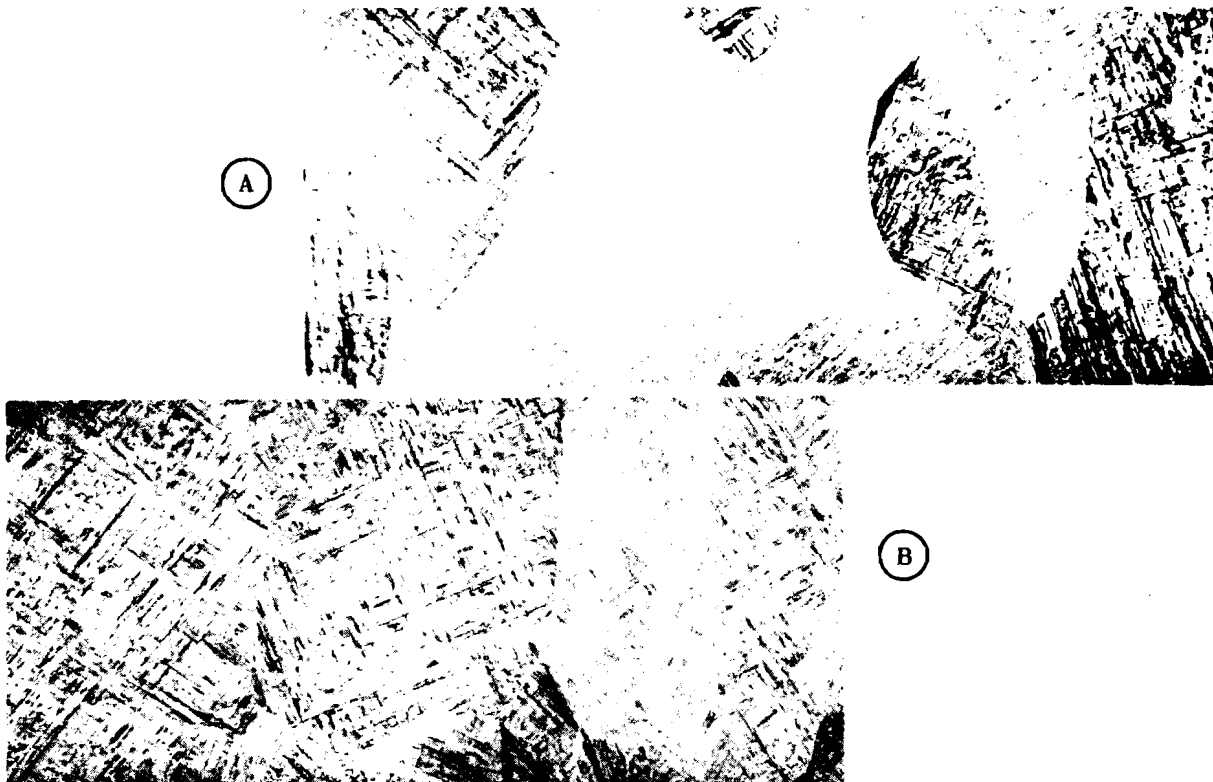


FIGURE 1

- (c) Cryogenic treatment of welding gas did not produce any detectable metallurgical changes in the weld behavior of a titanium-6 aluminum-4 vanadium alloy.



FIGURE 2 SAMPLE WELDED WITH ULTRASONIC TREATMENT
(50X, Kroll's Reagent)

RECOMMENDATIONS

- (a) Improved metallurgical features effected by the introduction of ultrasonic vibrations during the fusion welding of one titanium alloy supports the desirability for further study of this treatment.
- (b) Experimental effort should be directed toward the use of vibratory power during the joining (fusion) of the refractory metals; tungsten, columbium, molybdenum and/or their alloys.
- (c) Laboratory apparatus, including instrumentation should be constructed for measuring the net acoustic energy delivered to the weld zone and to permit a realistic appraisal for subsequent manufacturing consideration.

DEVELOPMENT

Russian literature published in 1957 (Ref. a) disclosed the effect of ultrasonic vibrations on the crystallographic behavior during the solidification of stainless steel ingots. In this instance, the typical as-cast microstructure was rearranged to the more desirable, uniform, equi-axed pattern. Mechanical property data portrays, most

markedly, the beneficial effect of high frequency vibrations. Work of a similar nature undertaken by U. S. investigators in 1958 (Ref. b) confirmed the Russian studies. Recent Soviet accomplishments in the field of ultrasonics (Ref. c, d and e) have demonstrated that the introduction of high frequency vibrations in the weld puddle promotes the formation of a fine, uniform grained weld pattern. Resultant mechanical properties affirm the metallurgical value attached thereto.

The increasing use of critical aerospace structures made from the refractory metals has created a need for a method of fabrication that will permit the design of complex welded assemblies possessing suitable engineering properties. That segment of our study dealing with ultrasonics affirms, in small measure, the more extensive work conducted in Russia. It is conceivable that their experimental effort will ultimately bear more directly upon the use of vibrating power for the joining of refractory metals. Metallurgical assurance that disastrous grain coarsening during welding can be averted through the use of ultrasonic vibrations is certain to broaden the application of these materials for severe aerodynamic requirements.

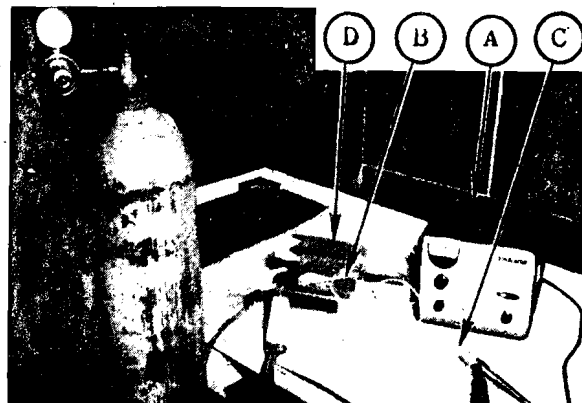


FIGURE 3

Test equipment used during the development of this project is shown in Fig's. 3 and 4.

The ultrasonic vibration apparatus appears in Fig. 3, the major features being: (A) Ultrasonic Generator, (B) Transducer Coupling Device, (C) Welding Torch, (D) Workpiece.

The refrigeration apparatus is shown in Fig. 4. The designated features being: (A) Refrigerated Weld Fixture, (B) Welding Torch containing effluent refrigerated welding gas, (C) Instrument (potentiometer) for temperature measurements.

Methods and Results are presented in Tables 1 through 5.

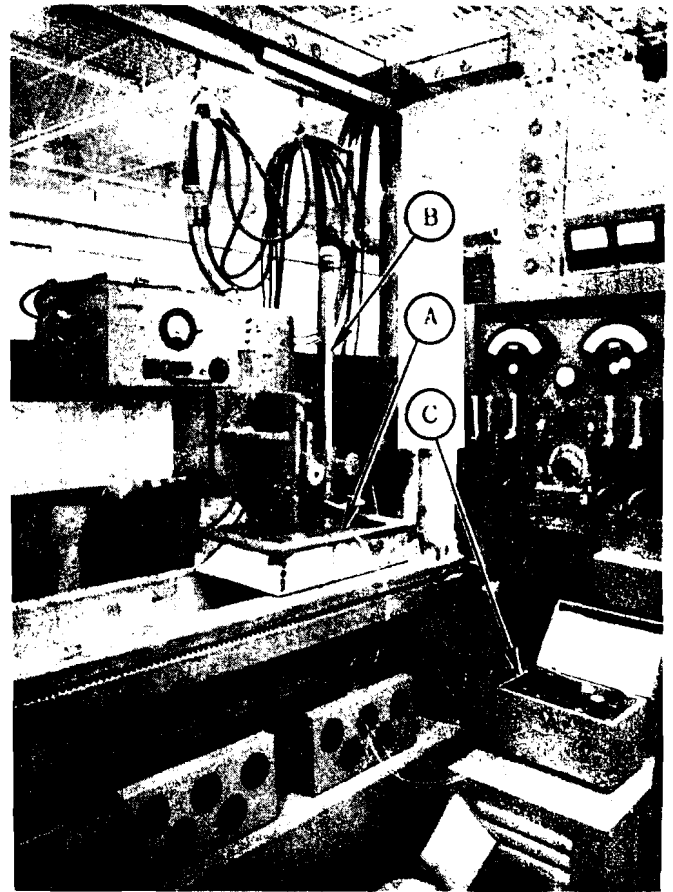


FIGURE 4

VALUE ANALYSIS

This study clearly demonstrates the value of ultrasonic treatment for one material that undergoes metallurgical decay when subjected to conventional or sophisticated welding practices. Since the action of the ultrasonic treatment is purely mechanical it follows that such difficult materials as molybdenum, columbium, tungsten or others should respond in similar fashion.

No quantitative appraisal of direct cost can be given at this time. It should be apparent, however, that possession of this auxilliary apparatus will permit the successful fabrication of complex structures made from the refractory metals.

REFERENCES

- a. Gurevich, Leontov and I. I. Teumin, Brutcher Translation No. 4035 - (Russian)
- b. Unterweiser, Iron Age, September 11, 1958
- c. Alov and Vinogradov, Brutcher Translation 4670 (Russian)
- d. Erokhin, Kogan, Silin et. al., Brutcher Translation 4905
- e. L. L. Silin, Brutcher Translation 4906 (Russian)

TABLE 1
CHEMISTRY FOR TITANIUM, 6 AL. - 4V ALLOY

<u>Element</u>	<u>Weight Percent</u>	
	<u>Nominal</u>	<u>Test Material</u>
Aluminum	5.5/6.5	6.15
Vanadium	3.5/4.5	3.42
Carbon	0.1 maximum	0.03
Iron	0.30	0.10
Nitrogen	0.05 maximum	0.023
Hydrogen	0.0150	0.0087

TABLE 2

SAMPLES WELDED WITH EXTREME PURITY HELIUM AND ARGON - TEST A

<u>Bend Radius</u>	<u>Results</u>
4T	failed
5T	failed
6T	failed
7T	failed

TABLE 3

SAMPLES WELDED WITH ULTRASONIC VIBRATIONS,
GENERATOR OPERATED AT MAXIMUM CAPACITY (40 Kc) - TEST B

<u>Bend Radius</u>	<u>Results</u>
4T	failed
5T	satisfactory
6T	satisfactory

TABLE 4

SAMPLES JOINED WITH REFRIGERATED WELDING GAS - TEST C

Welded At	Bend Radius	Results
Room Temp.	4.0T	failed
"	6.0T	"
"	7.5T	"
"	8.75T	"
"	9.30T	"
Room Temp.	10.0T	satisfactory
-14°F	4.0T	failed
"	6.0T	"
"	7.5T	"
"	8.75T	"
"	9.30T	"
-14°F	10.0T	failed
-73°F	4.0T	failed
"	6.0T	"
"	7.5T	"
"	8.75T	"
"	9.30T	"
"	10.0T	failed
-158°F	4.0T	failed
"	6.0T	"
"	7.5T	"
"	8.75T	"
"	9.30T	"
-158°F	10.0T	failed
-190°F	4T	failed
"	6T	"
"	7.5T	"
"	8.75T	"
"	9.3T	"
-190°F	10.0T	failed
-280°F	4.0T	failed
"	6.0T	"
"	7.5T	"
"	8.75T	"
"	9.3T	"
-280°F	10.0T	failed

WELDING SCHEDULES

	Test A High Purity Welding Gas	Test B Ultrasonic Treatment	Test C Refrigerated Welding Gas
Current, amps	42	42	42
Voltage	12.5	12.5	12.5
Speed ipm	20	manual	20
Gas mixture (torch)	Argon, 30 cfh Helium, 10 cfh	Argon, 30 cfh Helium, 10 cfh	Argon, 15 cfh
Gas (back-up)	Argon, 10 cfh	Argon, 10 cfh	Argon, 20 cfh
Gas (trailing shield)	Argon, 45 cfh	Argon, 45 cfh	None
Back-up (metal)	Copper	Copper	Copper
Electrode material	1/16 inch tungsten (2% thoriated)	1/16 inch tungsten (2% thoriated)	1/16 inch tungsten (2% thoriated)
Torch cup	No. 8 ceramic	No. 8 ceramic	No. 8 ceramic
Weld Joint Configuration	Square butt, no root opening	Square butt, no root opening	Square butt, no root opening
Basis material	Titanium, 6 Al-4V .040 inches thick	Titanium, 6 Al-4V .040 inches thick	Titanium, 6 Al-4V .040 inches thick